Jet Propulsion Laboratory
California Institute of Technology

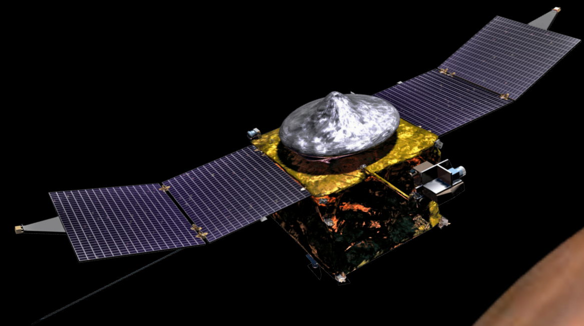
Exploring Martian subsurface through a new approach of monitoring Martian trace gases in future missions.

Nathan Barba, Sona Hosseini, Vlada Stamenković, Christopher Webster, Yen-Hung Wu, Tom Komarek, Ryan Woolley.

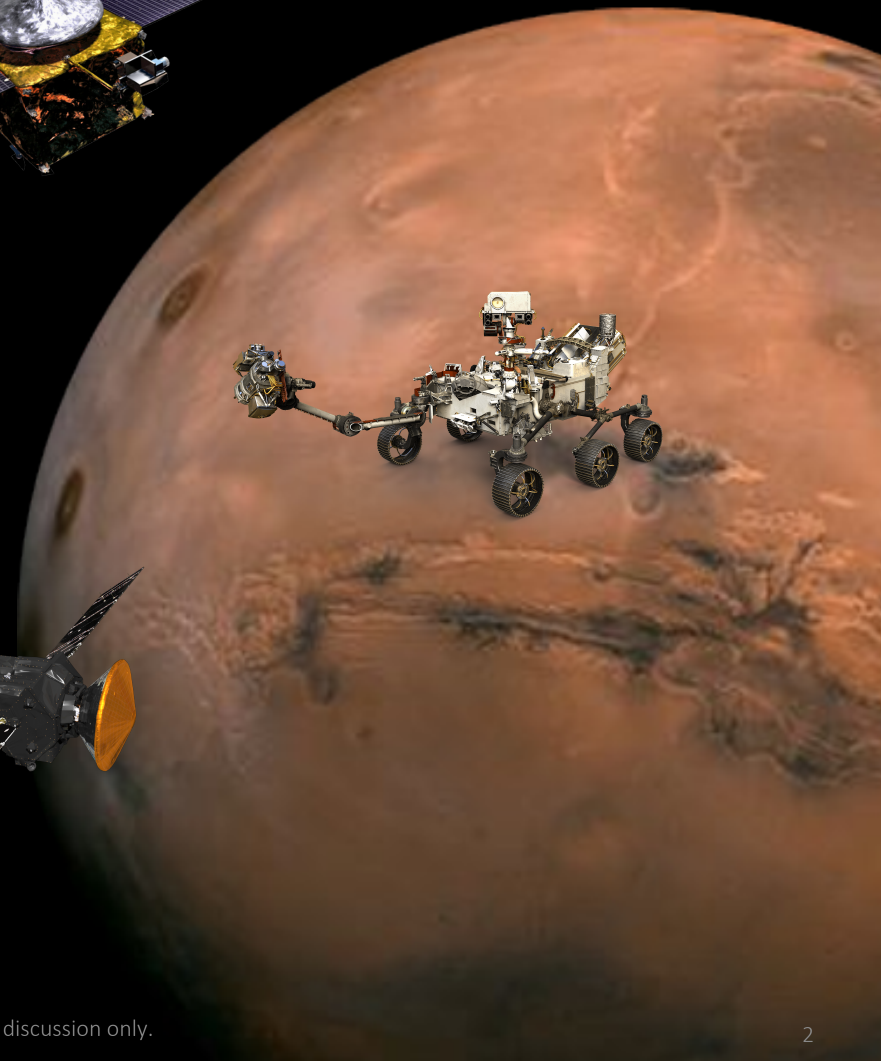
AGU Fall Meeting 2018

Current Mars trace gas science investigations

Mission: NASA Mars Atmosphere and Volatile Evolution Mission (MAVEN)
Launch Date: 2013
Gas Instrument: NGIMS
Spacecraft Mass: 809 kg
Location: Low Mars Orbit



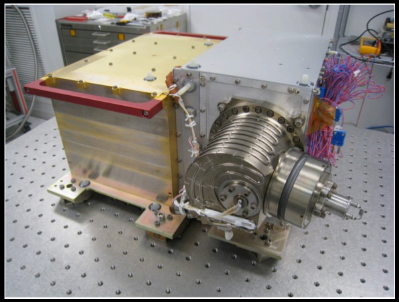
Mission: NASA Mars Science Laboratory
Launch Date: 2013
Gas Instrument: TLS within SAM
Location: Gale Crater, Mars surface



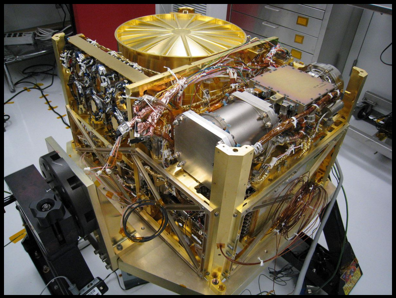
Mission: ESA ExoMars Trace Gas Orbiter
Launch Date: 2013
Gas Instrument: NOMAD
Spacecraft Mass: 3732 kg
Location: Low Mars Orbit

Pre-decisional. For planning and discussion only.

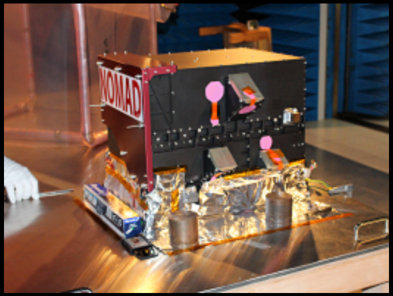
Heritage Gas Spectrometers



NGIMS - Neutral Gas and Ion Mass Spectrometer
Credit: NASA/GSFC



SAM – Sample Analysis at Mars
Credit: NASA/JPL



NOMAD – Nadir and occultation for Mars Discovery
Credit: Belgian Institute for Space Aeronomy

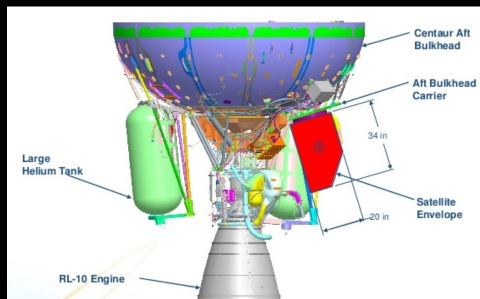
	NGIMS	SAMS	NOMAD
Mass (kg)	12	33	13.5
Dimensions (cm)		55 x 42 x 31	49 x 35 x 21
Power (W)	40	800	6

Emergence of smaller interplanetary spacecraft

- Picture shown to the right, of Mars from MarCO CubeSat
- This is the first step towards deep-space science investigation using small spacecraft.
- Next steps, will enable science performed by small spacecraft.

MarCO-B 6U CubeSat capturing an image of Mars from altitude of 6000 km.
Credit: NASA/JPL-Caltech

Three Key Methods to Get Small Spacecraft to Mars



Source: ULA ABC User's guide

Small spacecraft mounded on Aft Bulkhead Carrier (ABC)

Source: NASA

Deep Space 2 piggyback released prior to arrival on Mars Polar Lander Mission in 1999.

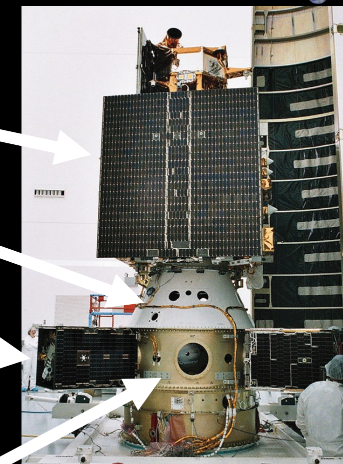
Many small LVs are in development for Earth/Moon use. Firefly + solid motor would be capable to reach Mars. Others may follow.

Primary Payload

Primary Payload Adapter

Secondary Payload

ESPA Ring Adapter



Science Test Payload STP-1 (USAF 2007) Payload Stack
Source: Aerospace.org

	① Piggyback on Mars Bound Mission		② Small Launch Vehicle + Solid	③ Rideshare as Secondary P/L on ESPA
	release after launch	release prior to arrival		
Dry mass to Mars	< ~80 kg for ABC	mission specific	~200 kg	< ~250 kg
Launch Cost	Minimal	minimal	~ $15 M	< $15 M
Launch Opportunity Frequency	Once every 2 years	Once every 2 years	As needed	~10 launches to GTO per year

Areostationary Concept Case Study

Features

Mass: 220kg to 350kg per spacecraft

Target: Mars – Areostationary Orbit (17,000 km)

Configuration: Single spacecraft, future constellation.

Launch: Secondary Payload on ESPA Grande

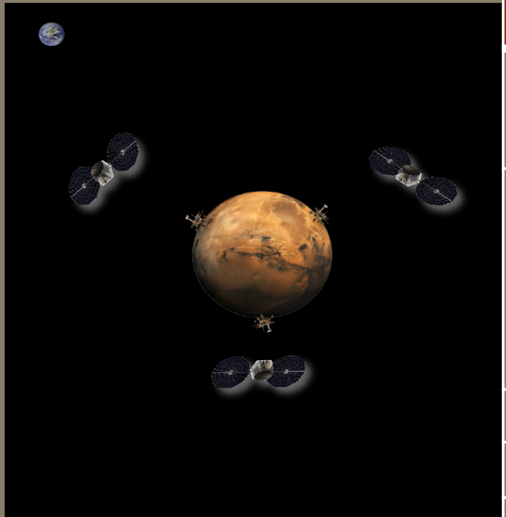
Cruise: Solar electric propulsion

Enabling Technology: None required

Risk Class: D

Cost : $100 M to $200 M per spacecraft

Lifetime: ~3 Earth years on orbit then replenished.

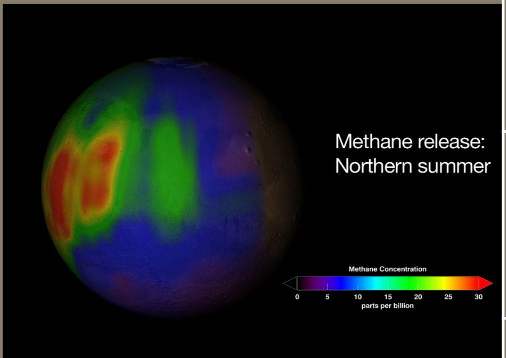


Science and Instruments

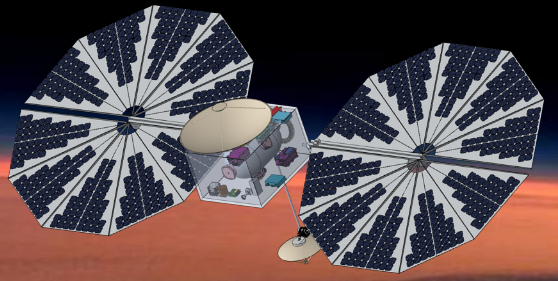
- Localization and diurnal concentrations of methane, other trace gases, and water.
- Spatial Heterodyne Spectrometer (JPL)
- TBD - Camera

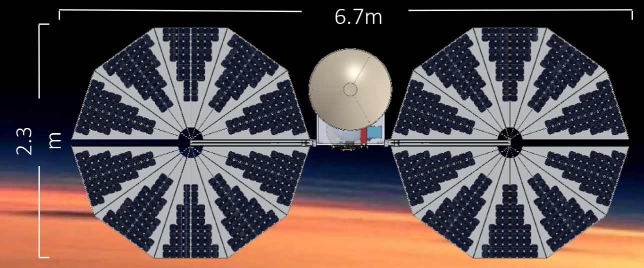
Telecom

- X-Band proximity link to surface, MSL-like rates.
- Ka-Band, Direct to Earth, MAVEN-class data rates.



System	Option A
Delta-V	• Spiral out: 1.6 km/s • Cruise: 5.7 km/s • Spiral in: 0.9 km/s
Telecom	• DTE: Ka-band dedicated, X-band backup and DFE • Optional crosslink • Body fixed antenna, and solid state power amplifier.
Propulsion	• 2x MaSMi Hall Thrusters
ACS	• 0.2 deg
Power	• 2.1kW(BOL) lightweight SA • Secondary batteries – 250Wh capacity
C&DH	• Dual-Core LEON3FT (SPHINX), 100MHz, 8GB NAND Interfaces: RS422, SPI, I2C, Spacewire, GPIO, UART
Mechanica l	• ~1m x ~1m x ~1m • Compatible with ESPA/ESPA Grande
Payload	• Spatial Heterodyne Spectrometer • Multispectral Wide Field





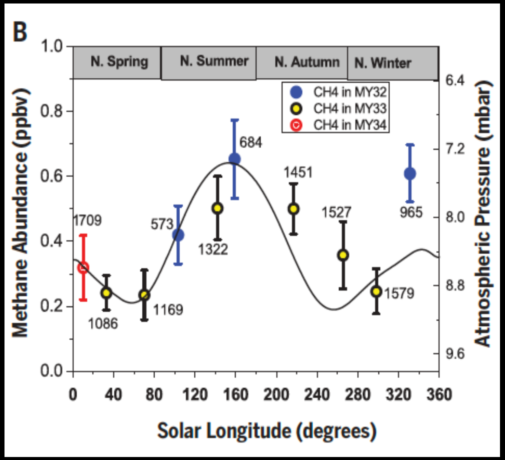
Trace gas science concept for Mars

Jet Propulsion Laboratory
California Institute of Technology

Mars Formulation – Small Spacecraft Studies

Finding the Sources & Sinks of Trace Gases

- **What is the global variability/causality of trace gases?**
- **Where are sources?**
- **Where are sinks?**
- **Are they close to the surface or in the atmosphere.**
- **Focus on (1) methane & water, (2) isotopologues of methane and water, (3) oxygen and (4) heavier hydrocarbons (e.g., ethane).**



Webster + (2018)

Constrain the diurnal variability of condensable species

- Req. Objective 1: diurnal concentration of methane.
- Req. Objective 2: diurnal concentration of water.
- Objective 3: diurnal concentration of methane isotopologues.*
- Objective 4: diurnal variation of the D/H ratio.*
- Objective 5: diurnal concentration of O_2.*
- Objective 6: diurnal concentration of heavier hydrocarbons.

Science measurements

- Ppb vol levels of
  - Methane & water,
  - isotopologues of methane,
  - D/H ratio,
  - Oxygen,
  - heavier hydrocarbons,
  - on less than 50x50 km,
  - Aiming for 20x20 km.
- Temperature & pressure.

Pre-decisional. For planning and discussion only.

Multichannel Spatial Heterodyne Spectrometer

Measurement Objectives

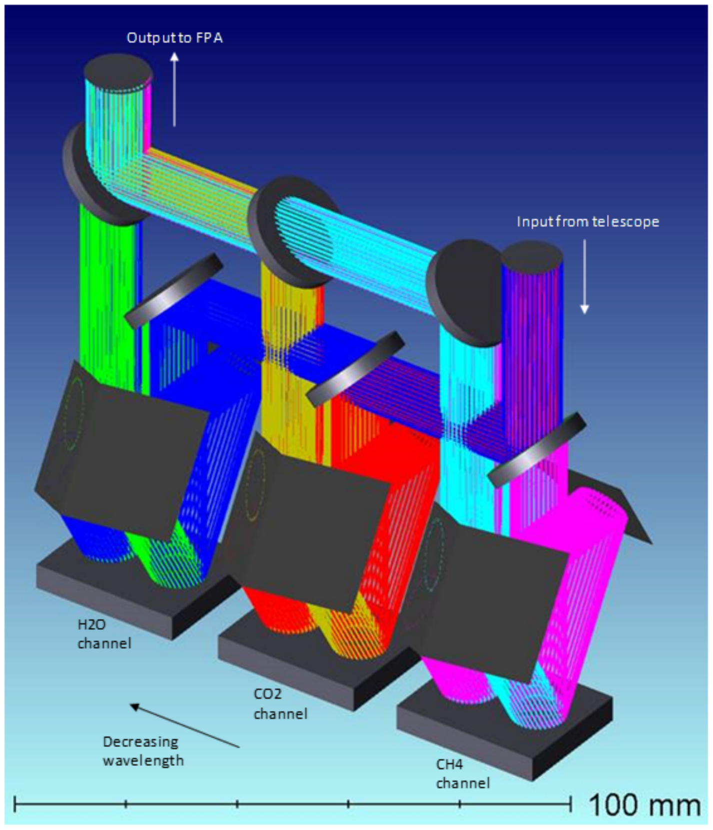
Localize sinks and sources of methane and their daily and seasonal variability.

Measurement Requirements

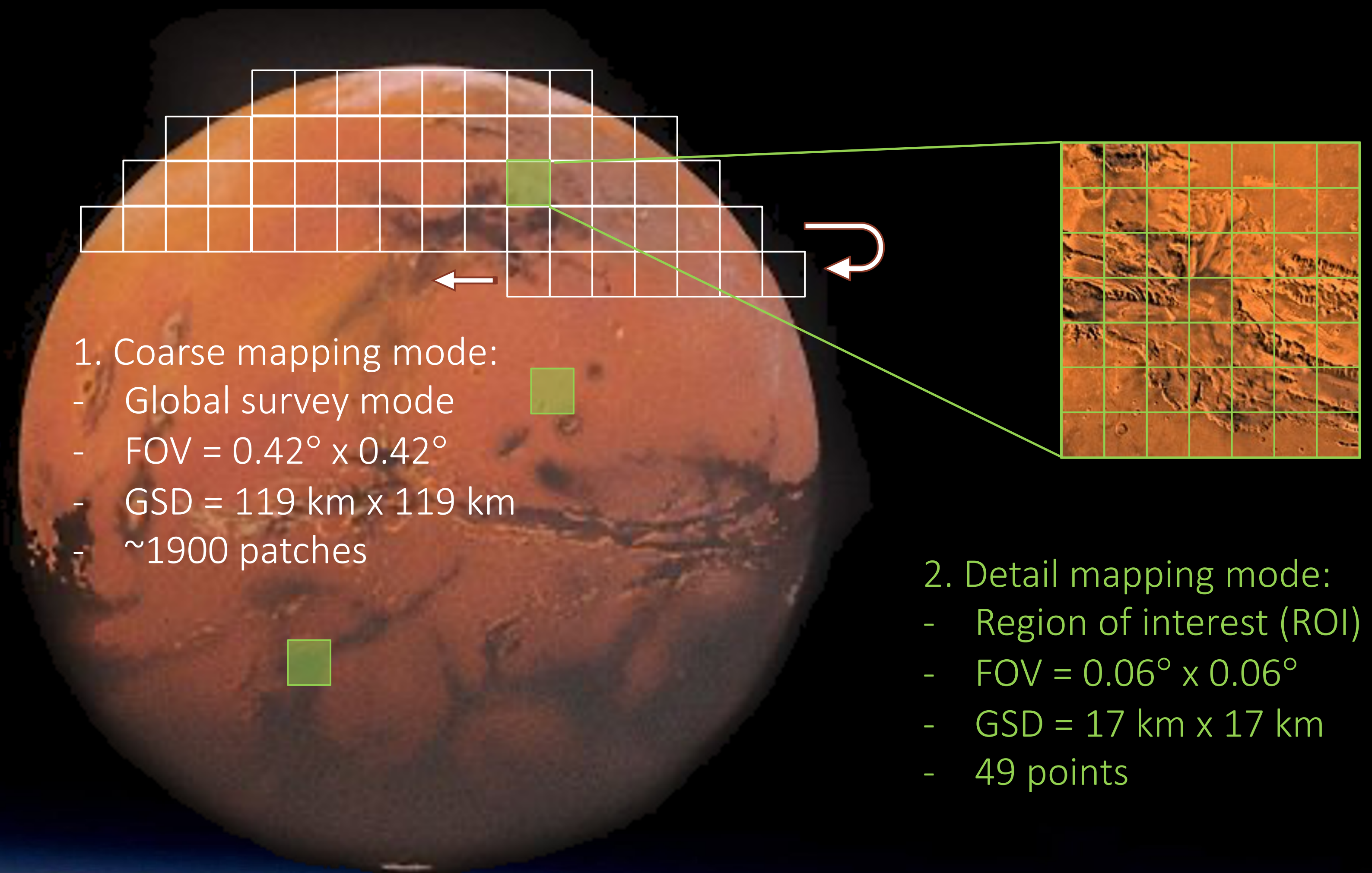
- Sensitivity of 0.1 ppbv.
- Spatial resolution for localization: threshold 60 km, baseline is 20 km.
- Daily coverage of whole disk unless object of interest identified.

Data Products

Daily map of methane and water fluxes, threshold one Martian Year, baseline two Martian year.



Conceptual Operational Scenario for SHS



1. Coarse mapping mode:
- Global survey mode
- FOV = 0.42° x 0.42°
- GSD = 119 km x 119 km
- ~1900 patches

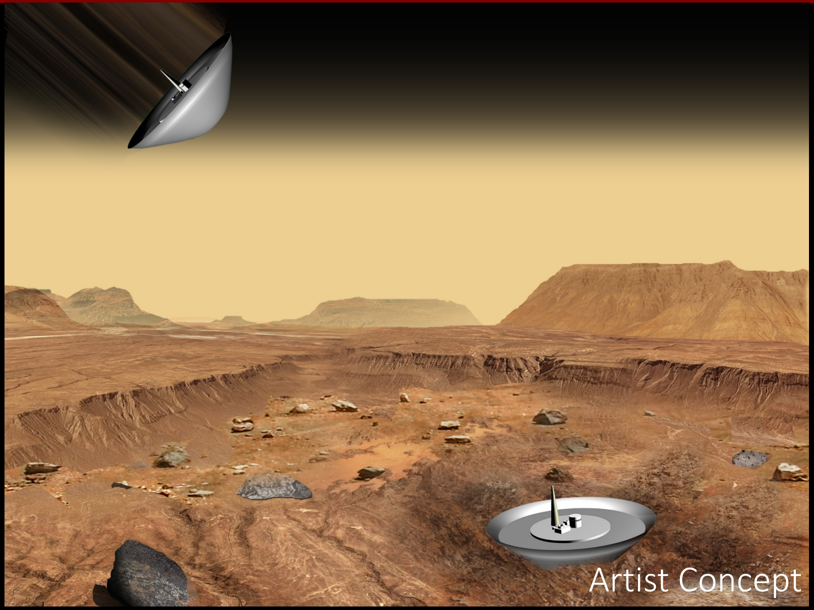
2. Detail mapping mode:
- Region of interest (ROI) identified
- FOV = 0.06° x 0.06°
- GSD = 17 km x 17 km
- 49 points

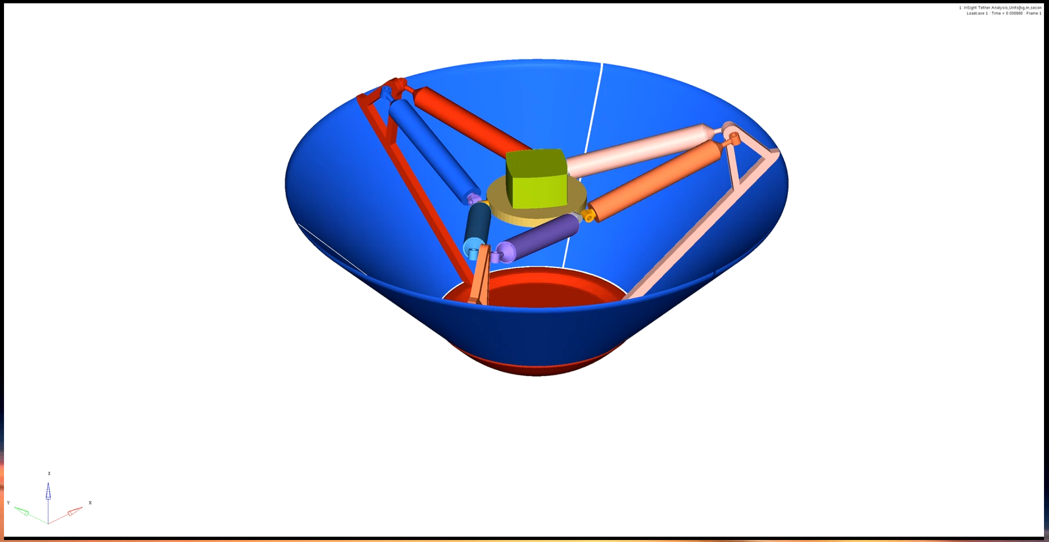
Complimentary science with orbiter and surface instruments.

- In order to characterize and localize sources and sinks of methane we need to see the whole atmospheric column down to the surface.
- We may miss emissions close to the surface which cannot be measured with orbiter missions in limb.
- Need a technically feasible and cost effective method to deliver science payloads to the surface of Mars.

Mars Surface Concept Case Study - SHIELD

- SHIELD enables the delivery of scientific payload affordably to the surface of Mars.
- Total science payload range 0.5 kg to 1 kg.
- Science payload can vary between liquid water sounders, trace gas sniffers, meteorological stations, and electromagnetic field sensors.
- Impact g (with 200mm stroke) ≈ 900 G
- Science goals of high priority for Decadal science, MEPAG, and HEO SKG's.
- Missions can consist of multiple SHIELD landers.





Thank you

Nathan Barba

Jet Propulsion Laboratory

Systems Engineer

Advanced Design Engineering Group (312D)

nbarba@jpl.nasa.gov

(818) 354-2688